BACTERIOLOGICAL WATER QUALITY

OF

MISSISSIPPI LAKE

1976

MICROBIOLOGY SECTION

LABORATORY SERVICES BRANCH

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DESIGN OF THE SURVEYS

Timing:

Measurements over five consecutive days at a sampling location are regarded as a reliable number to be taken to arrive at a sound bacterial density value. When many lake stations are sampled in this manner, a reproducible bacteriological picture of the lake is obtained.

The northern and southern halves of the lake were examined separately. Two consecutive five-day bacteriological water quality surveys were carried out between May 28 and June 6, and July 20 and July 29. Three-day bacteriological sediment surveys of both halves of the lake were carried out between June 16 and June 21, and August 10 and August 15. A questionnaire, asking about the incidence of swimmer related disease in the previous year, was distributed to shoreline cottages throughout the summer.

Selection of Sample Locations:

The bacteriological sampling stations were located at the midlake, inflows, outflows and in areas considered to be representative of the various degrees of shoreline development found on the lake. Samples were taken at 75 shoreline locations, 5 midlake and 5 depth stations (Figs. 1, 2). The samples were taken 7-10 meters from shore, one meter below the surface, as well as one meter above the bottom of the 5 midlake stations. Sediment samples were taken by scooping up surface sediment and the water above it in a sterile bottle fitted in a clamp at the end of a sampling pole. Twelve locations were sampled in this manner.

Bacteriological Tests and Interpretation:

The number of bacteria in each of the four kinds of 'indicator' organisms were determined on each sample. The four kinds of bacteria, total coliform, fecal coliform, fecal streptococcus bacteria, and Pseudomonas aeruginosa are all indigenous to man and other warm-blooded animals, and are found in the

colon and feces in tremendous numbers. Many diseases common to man can be transmitted by feces; consequently, the probability of occurrence of these diseases is highest in areas where the water is contaminated with fecal material. These indicator organisms in water connote the possible presence of disease causing organisms.

The density of the indicator bacteria in water will vary considerably between samples taken at the same station, or at different stations on a lake, or if taken at different times, and so the assessment of water quality cannot be determined accurately from a single water sample. Therefore, the bacteriological surveys require many samples to be taken at several lake stations over a period of time. The large amount of data obtained is reduced by calculations to meaningful and easily manipulated statistics.

These data were then evaluated by statistical techniques in the following manner. The geometric mean, the most appropriate central value and variance were calculated for the values of each of the four kinds of bacteria at every station, providing concise valid data. Statistically significant variations in the bacterial densities between stations, or groups of stations, was determined by a One-Way Analyses of Variance and Bartlett's Test of Homogeneity. By these means, the data from each station were tested against that of every other station until all stations with similar geometric mean densities were separated into groups (Group A, B).

The group results and those for individual stations were identified by different stippling. Within each stippled area, the group geometric mean applied for each type of bacteria unless otherwise indicated by individual station values. The areas of better or worse bacterial densitites were defined by the group geometric mean densities, and so any inputs of bacterial contamination, and the area they affect, were identified.

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The effect of present development on Mississippi Lake can be estimated by comparison of developed and undeveloped sections of the lake, or by comparison to an undeveloped lake, like Jerry Lake (1).

Present Status of the Lake

Water Quality:

In May and June, 1976, the bacteriological water quality of the main body of water of Lake Mississippi was good and within the M.O.E. microbiology criteria for total body contact recreational use. In July, the bacteriological water quality had deteriorated and was poorer than most lakes previously studied in that part of Ontario. The entire northern half of the lake and many localized areas had bacterial levels which approached or exceeded the Recreational Criteria for total body contact use which states:

> "Where ingestion is probable, recreational waters can be considered impaired when the coliform (TC), fecal coliform (FC) and/or enterococcus (fecal streptococcus, FS) geometric mean density exceeds 1000, 100 and/or20 per 100 ml respectively, in a series of at least ten samples per month, ..."[2].

1. Report of Water Quality in Jerry Lake, an uncottaged lake in Sinclair Twp. in the Muskoka's 1972-1973 MOE 39p.

(2) Guidelines and Criteria for Water Quality Management in Ontario - MOE 1974

In June, the geometric mean bacterial densities for the main body of water for the southern half of the lake were 9 TC, 3 FC and 3 FS per 100 ml (Group A, Fig. 3). A heavily cottaged section of the eastern shoreline of the narrows showed bacterial levels greater than the main body of water with 11 TC, 11 FC and 3 FS per 100 ml (Group B, Fig. 3). The Mississippi River inflow had higher bacterial levels than the larger body of the lake with 12 TC, 12 FC and 3 FS per 100 ml (Group C, Fig. 3). Inflowing streams often have higher bacterial levels than the rest of the lake as they can carry materials such as soil, decaying matter and possibly animal and human wastes into the lake. Elevated fecal coliform levels were found at several scattered locations. The geometric mean concentrations are shown below:

Station or Group	FC/100 ml	FS/100 ml
B	11	3
C	12	3
38	42*	3
41	11	9
44	29*	3
45	29*	3
46	7	3
53	21*	3

A comparison of the densities of fecal coliform and fecal streptococcus for some of these locations (*) indicated that some of the fecal bacteria were probably of a human origin. Pseudomonas aeruginosa was not detected in this half of the lake.

The geometric mean bacterial densities for the northern half of the lake were homogenous with 12 TC, 6 FC and 5 FS per 100 ml (Group A, Fig. 4). At three locations on the eastern shore (stations 7, 13 and 20), there were tendencies for higher fecal coliform levels, although statistically these levels were

homogeneous with the main body of water. The proportion of fecal coliforms and fecal streptococci indicated that some of the contamination was probably of human origin. Pseudomonas aeruginosa was isolated at several locations in very low concentrations (Stns. 10D, 72, 75, 76, 80).

In July, the geometric mean bacterial densities for the main body of water in the southern half of the lake was 38 TC, 3 FC and 13 FS per 100 ml (Group A, Fig. 5). The Mississippi River inflow area had bacterial levels of 38 TC, 3 FC and 53 FS per 100 ml (Group B, Fig. 5). The fecal streptococcus levels in this area exceeded the M.O.E. microbiology criteria for recreational use. Elevated fecal coliform or fecal streptococcus levels were found at several other scattered locations. These geometric mean densities are shown below:

Station	FC/100 ml	FS/100 ml
26	17	13
31	3	173
47	20	70
45	18	13
57	16	13
53	20	13
60	3	123
62	3	90
63	3	67

Pseudomonas aeruginosa was not detected in the southern half of the lake.

The geometric mean bacterial densities for the main part of the northern half of the lake were 39 TC, 11 FC and 57 FS/100 ml (Group A, Fig. 6). A very heavily cottaged area along the most northern shoreline had elevated bacterial levels of 71 TC, 71 FC and 57 FS per 100 ml (Group B, Fig. 6). Another heavily cottaged area at station 23 had fecal coliform levels of 23 per 100 ml. Elevated

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fecal coliform levels were also found at the mouth of two inflowing streams (stations 13 and 70) with concentrations of 38 and 42 per 100 ml respectively. The fecal streptococcus levels throughout the entire northern half of the lake, 57 per 100 ml, exceeded the present Recreational Criteria. Many of the fecal streptococcus colonies were small and lightly coloured which is not their usual appearance. Some of these colonies, isolated from the northern half of the lake, were purified and sent to Toronto for identification. Of fifteen colonies, all were lactobacillus spp., the most common being Lactobacillus plantarum. This organism can be of fecal origin as it can be isolated from cattle dung(Bergey's Manual of Determinative Bacteriology, 8th Ed., Williams and Wilkins, Baltimore, 1974). The density of fecal streptococcus should be reduced by approximately 33% to correct for the presence of Lactobacillus plantarum. The corrected fecal streptococcus density, approximately 40 FS/100 ml, is still high and indicates some fecal contamination probably of animal origin. Pseudomonas aeruginosa was isolated at two locations on the northern shore, stations 72 and 76, in concentrations of 6 and 2 per 100 ml. The levels of the other parameters were also high in this general area, e.g. Group B, Fig. 6.

It has often been observed that following a rainfall, bacterial levels increase and remain elevated for several days. A rainfall effect is measured by an increase in fecal coliform and fecal streptococcus levels, following a rainfall, of greater magnitude than daily variations. In May and June, the daily changes in mean fecal coliform and fecal streptococcus densities were small, but rose abruptly following rainfall. This rainfall effect was large as it affected the main body of the lake as well as the inflowing streams and is illustrated for the spring survey (Fig. 7). On May 31 and July 20, a total of 0.73 inches if rain was recorded in a rainfall gauge on the shore of the lake and it appeared that many bacteria were washed out of the surrounding soil and into the lake.

The bacterial densities in the main body of water were generally higher in the summer than in the spring. In both spring and summer, the Mississippi River was the source of some fecal bacteria as bacterial densities in the river mouth were higher than the average for the rest of the lake. However, the concentrations of bacteria at the river mouth were not as great as many of the contaminated shoreline locations. Much of the contamination is a shoreline phenomenon and is probably linked to shoreline use such as farm, cottage and trailer camp development. In summer, the midlake surface and bottom waters (Stns. 5, 5D, 10, 10D, 29, 29D, 42, 42D) were lower than average which is consistent with a shoreline source of fecal bacteria in the lake. It was observed that rainfall in spring and summer was responsible for washing bacteria from the shore into the lake.

Sediments:

In June, the geometric mean densities for sediment were 614 FC and 110 FS per 100 g dry weight of sediment. An inflowing stream (Stn. 13) was much higher than average with 20,300 FC per 100 g dry weight. The public beach at Carlton Place (Stn. 2) also had higher than average values with 1,220 FS per 100 g dry weight. Fecal coliform densities showed a tendency to be higher in spring and summer at this public beach. Lower fecal streptococcus densities were found in the sediment at two cottaged locations on the eastern shore (Stns. 9, 18) with values of 21 and 14 FS per 100 g dry weight respectively.

In August, the fecal coliform geometric mean density for sediment was similar to the spring value but the fecal streptococcus density was much lower, values of 547 FC and 47 FS per 100 g dry weight were found. The ratio of bacteria in water and sediment was calculated for those locations at which both kinds of sample were taken.

Ratio of Bacteria in Sediment: Bacteria in Water

	Fecal Coliforms	Fecal Streptococcus
Spring	614/ 7.4 = 83	110/ 5.1 = 22
Summer	547/44.5 = 12	47/12.4 = 3.8

This shows the great potential of sediment to lower water quality if it is mixed into the water by the action of swimmers, boats, or wind and wave action.

Pseudomonas aeruginosa was isolated from the sediment in very low densities. Geometric mean densities are not as meaningful as the number of samples in which the bacterium was present. In Mississippi Lake sediment 19.7% (i.e. 14/78 samples) were positive for P. aeruginosa. The median value for fecal coliforms in sediment was 436 per 100 g dry weight. These values were then plotted on a graph (Fig. 8) showing "A Between Lakes Comparison of P. aeruginosa in Sediment". The original material was taken from a recent M.O.E. study ('Assessment of the Use of Bacteriological Determinants to Study the Effects of Recreational Activity/ Development on Lake Water Quality', by P.L. Seyfried. MOE 136p, 1976). Mississippi Lake is closer to the more polluted lakes, like Muskoka Bay and Three Mile Lake, rather than those having very appealing water quality, like Wood or Harp Lakes (Fig. 8). The correlation of P. aeruginosa and fecal coliforms suggested that the P. aeruginosa was of fecal origin.

P. aeruginosa can cause an infection of the external ear of bathers. The survey of cottagers in 1976 gave 3.44% (58 /of 1684 bathers) of bathers who complained of ear infections. Possibly some of these infections were due to causes other than P. aeruginosa. This would reduce the total number of swimming related infections. Therefore, the figure of 3.44%, though perhaps not very accurate, was the maximum possible number. When the data was compared with that of the recent M.O.E. survey previously quoted (P.L. Seyfried. MOE 1976), it was seen that

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the incidence of ear infections (3.44%) was low compared with that of other lakes. Ear infections are related to the amount of swimming done as well as the presence of P. aeruginosa in water. Perhaps the unappealing water quality of Mississippi Lake discouraged frequent bathing and so reduced the incidence of infection.

A Comparison with Other Types of Lake Surveys

A Mississippi Conservation Authority survey of cattle watering sites on Mississippi Lake was carried out by Chris Maher in 1976. From the results of this survey we concluded that some of our sampling locations were close enough to be influenced by the cattle manure at these watering sites. The likely sampling locations were Stations 24, 38, 42, 45, 70, 78. All but one (Stn. 78) of these locations showed higher than average levels of fecal bacteria in either spring and/or summer surveys. It was concluded that the cattle watering sites were largely responsible for the lowering of water quality at these locations. Wind and wave action could easily move the contaminated water to other locations and contribute to a reduction of water quality in the rest of the lake.

The M.O.E. has not surveyed Mississippi Lake before 1976. The Public Health Unit at Perth has monitored a few locations on the lake for several years. In past years, geometric mean densities of fecal coliforms have approached or equalled the Recreational Criteria of 100 FC/100 ml. In 1976, the values were lower than the Recreational Criteria and this was probably due to lower summer temperatures and increased rainfall in that year. The 1976 M.O.E. survey showed that fecal coliform levels were higher than other lakes surveyed in the area. Some locations on the lake had fecal coliform levels which approached the Recreational Criteria of 100 FC/100 ml. The annual variation in data collected by the Public Health Unit indicates that the Recreational Criteria for fecal coliforms can be equalled in some years with the present level of lake use. This situation must be a cause of concern.

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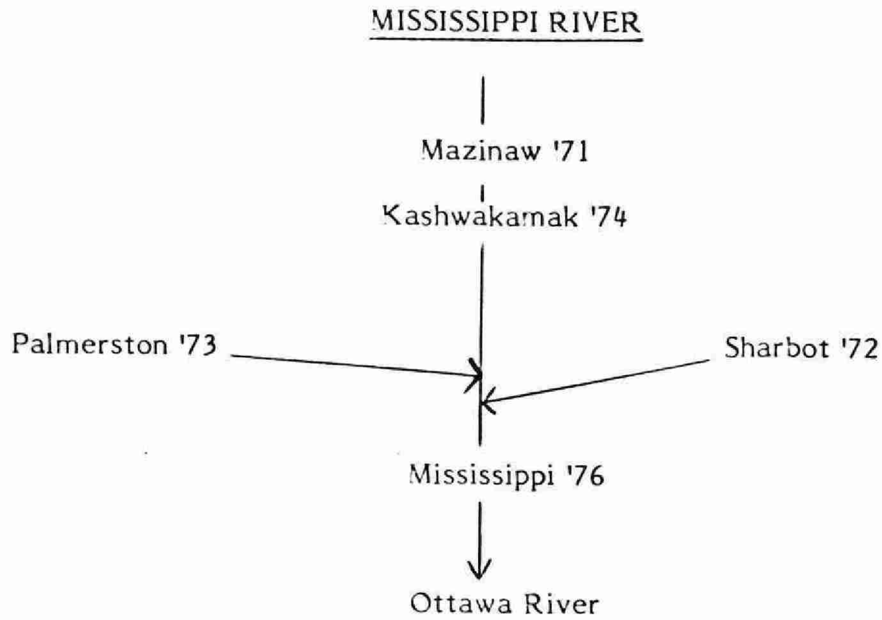
TABLE 1

Comparison of bacterial Levels in Mississippi Lake and other Lakes Draining into the Mississippi River

LAKE	FC/FS densities/100 ml for the main body of water (Group A ... etc.)		Number of single stations greater than the main body of water, excluding inflowing streams and exceeding 10/100 ml	
	SPRING	SUMMER	Number of High Shoreline Stns.	Maximum Value
Mazinaw	1/3 2/4	1/2	- -	- -
Kashwakamak	1/3	4/4	2 -	112 FC -
Palmerston	1/1	1/2	- -	- -
Sharbot	1/2	1/1	- 5	- 210 FS
Mississippi S ½	3/3 11/3 12/3	3/13 3/53	9	42 FC
N ½	6/5	11/57 71/57	5	173 FS

In past years, the MOE has surveyed four other lakes which flow into the Mississippi River. Their position in the drainage system is shown schematically below:



The bacteriological water quality of the main body of Mississippi Lake was much poorer than any of the other lakes surveyed in this drainage system. Furthermore, the shoreline contamination problems were also greater, and these were illustrated by the number of shoreline stations, excluding inflowing streams, greater than the main body of water and exceeding a mean density of 10 fecal bacteria/100 ml (Table 1).

Effect of Present Development on the Lake

The effect of present development on the lake has been demonstrated by these surveys. Levels of fecal bacteria far exceeded those found on an undeveloped lake [1]. The Mississippi River contributed to the low water quality by washing in fecal bacteria, but the main problem appeared to be contamination from the shoreline. In particular heavily cottaged areas, trailer camps and cattle watering sites appeared to be connected with contamination from the shore. Another source of fecal bacteria was rainfall runoff. Fecal coliforms were barely

detected in stormwater runoff from an undeveloped lake shore [1]. The rainfall effect can be more pronounced as lakes are developed. Finally, P. aeruginosa, a pathogenic bacterium, was isolated frequently from lake sediment. this bacterium was likely of fecal origin as numbers of pathogens correlated with fecal coliforms in a number of Ontario lakes. The origin of the P. aeruginosa was more likely human than animal.

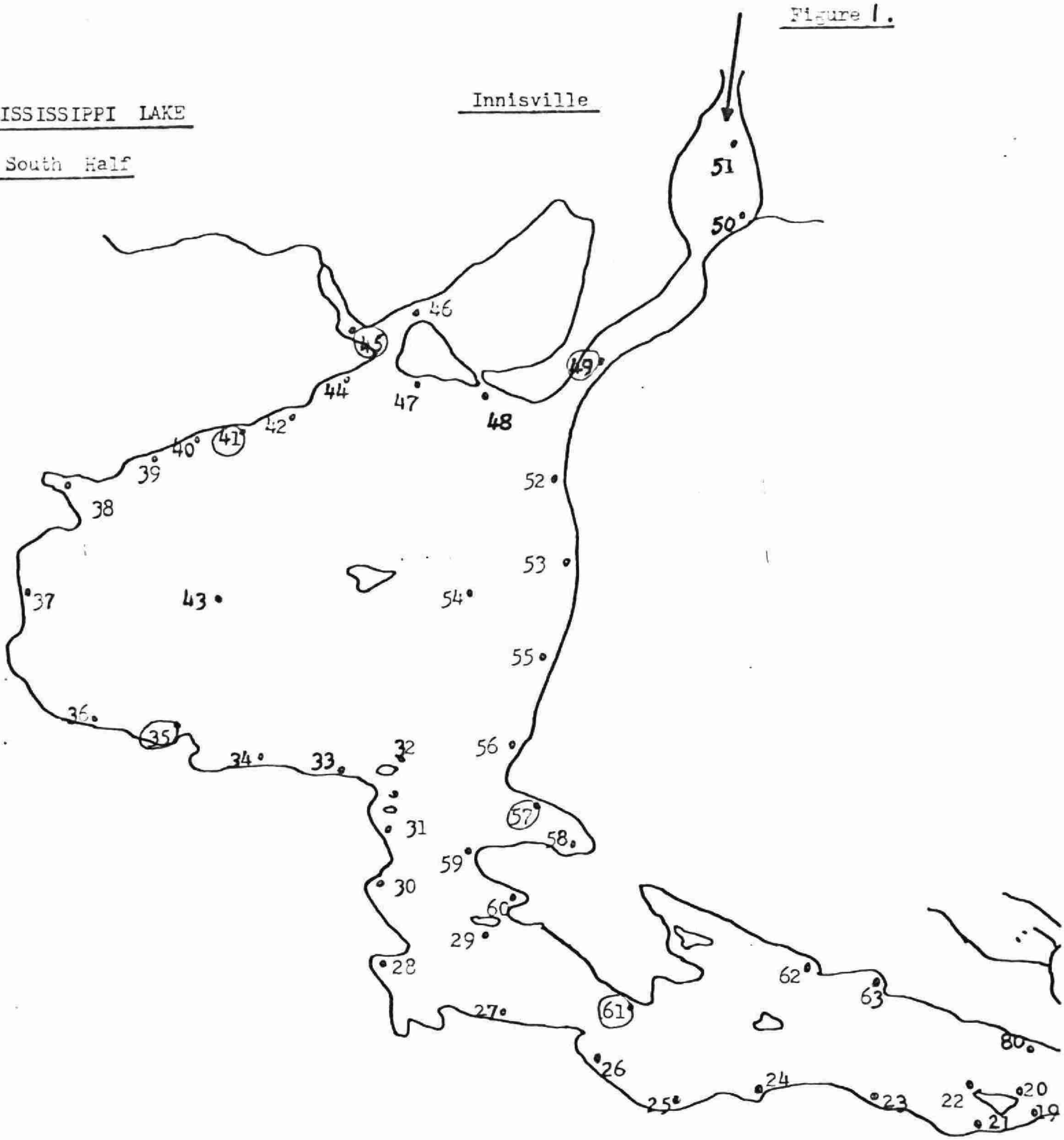
Acknowledgments

Samples of water and sediment were taken by a field crew supplied by the Mississippi Valley Conservation authority. The Pollution Control Program field crew distributed our questionnaire to cottagers. Microbiological analyses were carried out in a field laboratory by Andrea Toth, Lynne Kenton and Barbara Jeans. The final report was prepared by George Hendry and Andrea Toth.

Figure 1.

MISSISSIPPI LAKE

South Half



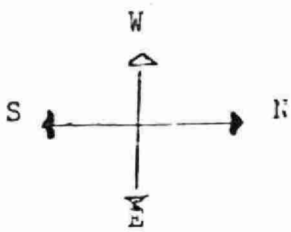


Figure 2.

MISSISSIPPI LAKE

NORTH HALF

17 - Water station
(13) - Water and sediment station

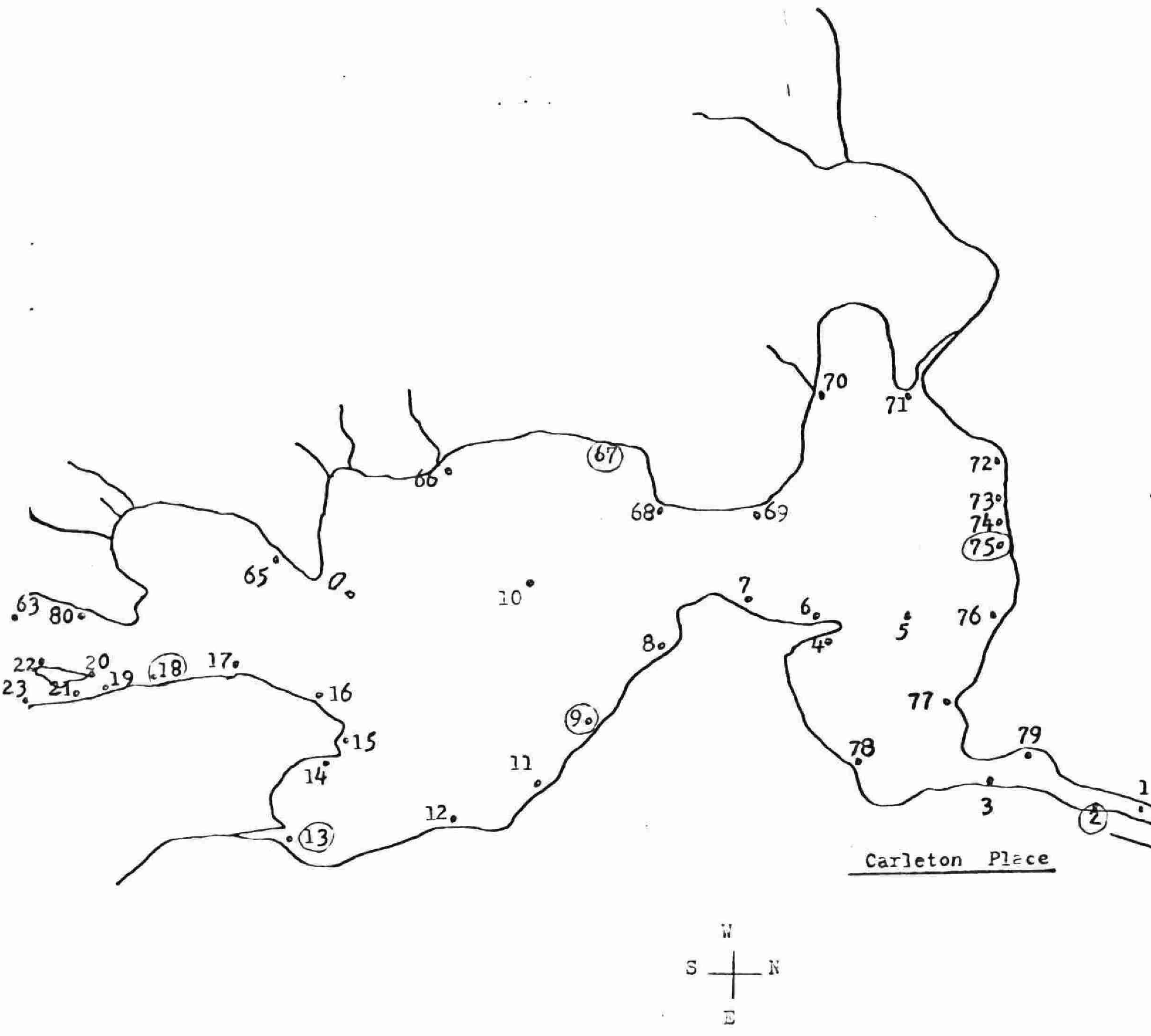


Figure 3.

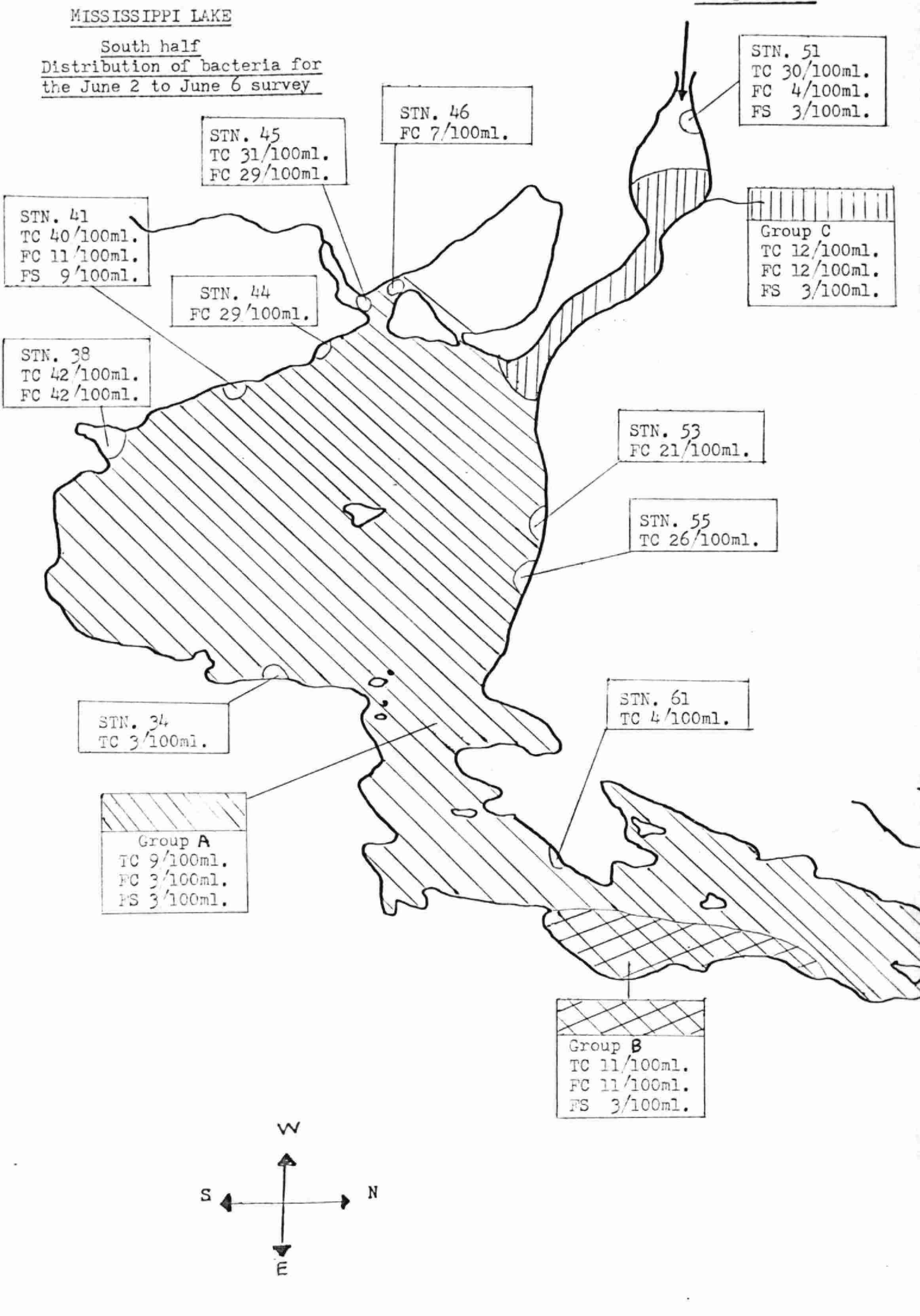
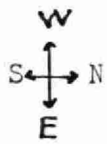

MISSISSIPPI LAKE
South half
Distribution of bacteria for
the June 2 to June 6 survey
STN. 51
TC 30/100ml.
FC 4/100ml.
FS 3/100ml.
STN. 46
FC 7/100ml.
STN. 45
TC 31/100ml.
FC 29/100ml.
STN. 41
TC 40/100ml.
FC 11/100ml.
FS 9/100ml.
STN. 44
FC 29/100ml.
Group C
TC 12/100ml.
FC 12/100ml.
FS 3/100ml.
STN. 38
TC 42/100ml.
FC 42/100ml.
STN. 53
FC 21/100ml.
STN. 55
TC 26/100ml.
STN. 61
TC 4/100ml.
STN. 34
TC 3/100ml.
Group A
TC 9/100ml.
FC 3/100ml.
FS 3/100ml.
Group B
TC 11/100ml.
FC 11/100ml.
FS 3/100ml.
W
S
N
E

Figure 4.



MISSISSIPPI LAKE

North half

Distribution of bacteria for

the May 28 to June 1 survey

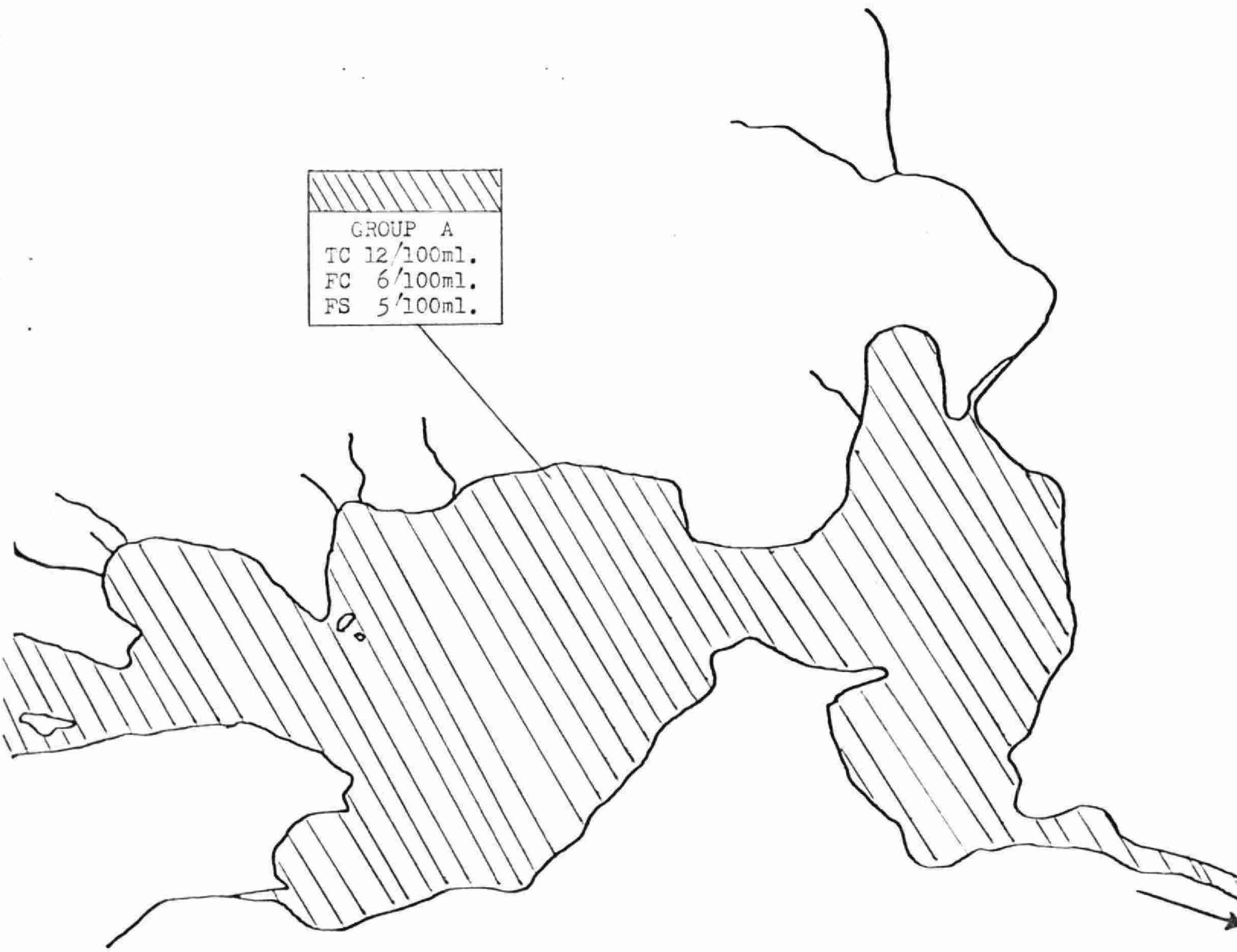


Figure 5.

MISSISSIPPI LAKE
South half
Distribution of bacteria for
the July 24 to July 29 survey

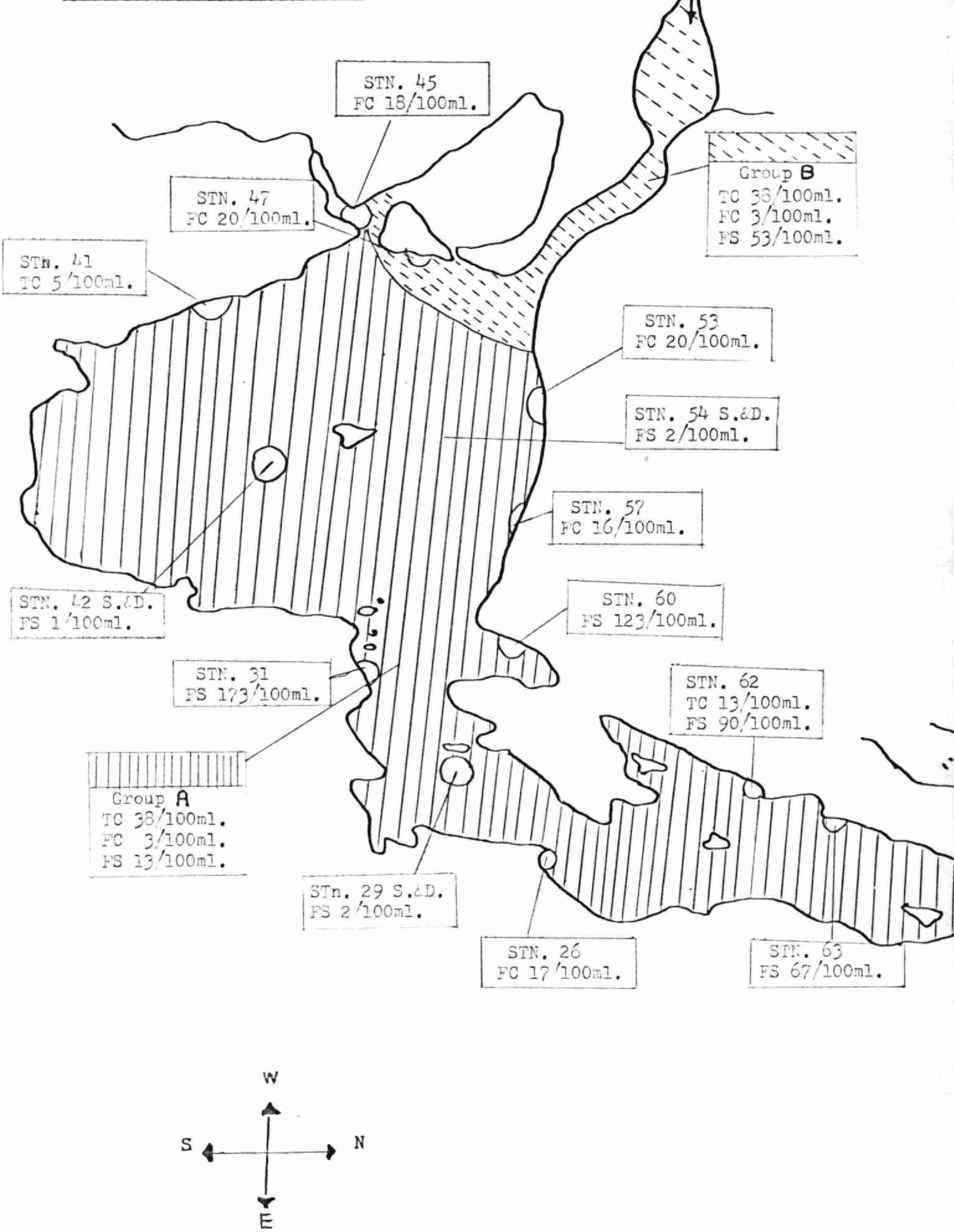
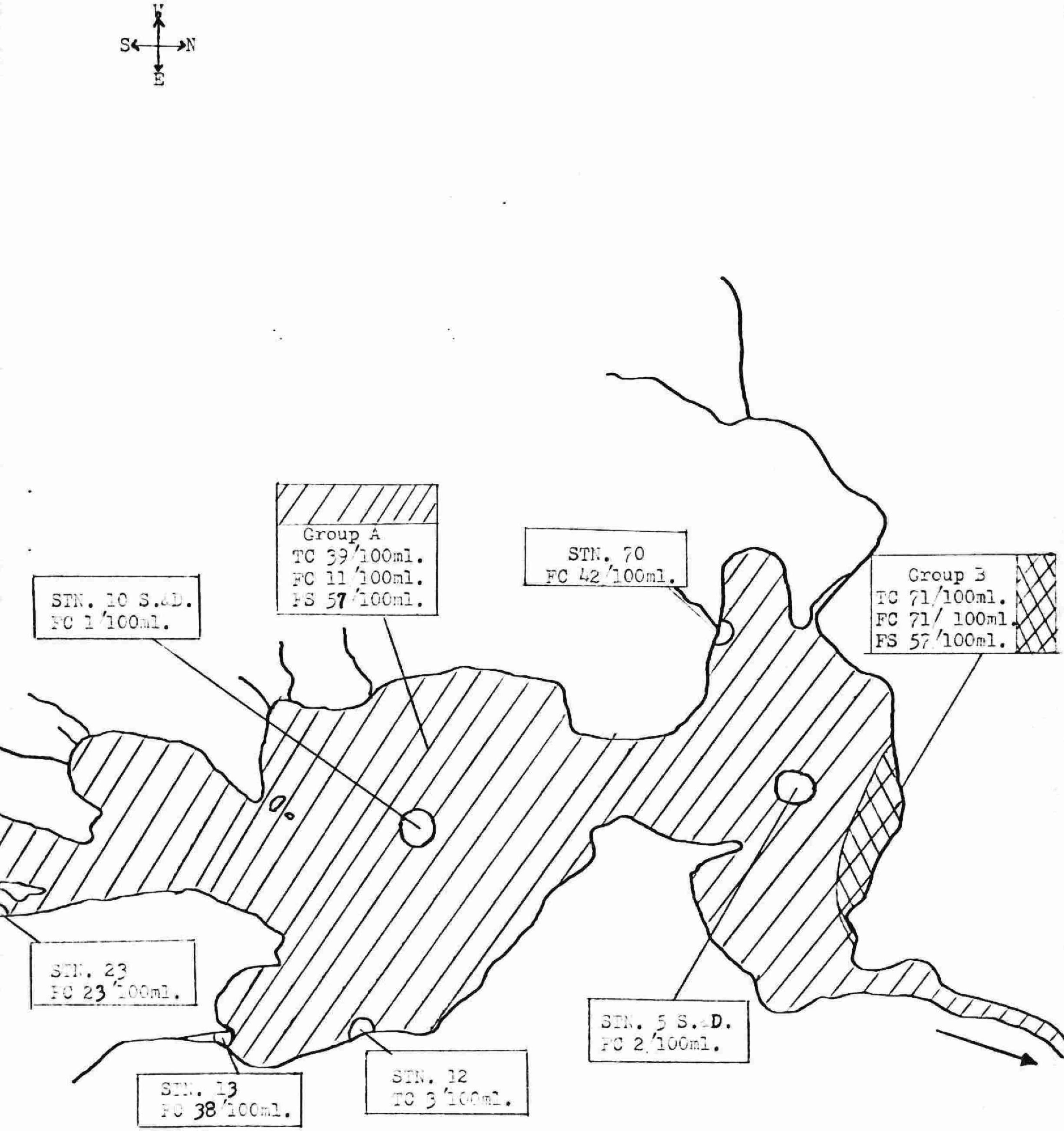


Figure 6.

MISSISSIPPI LAKE

North half

Distribution of bacteria for July 20 to July 24 survey



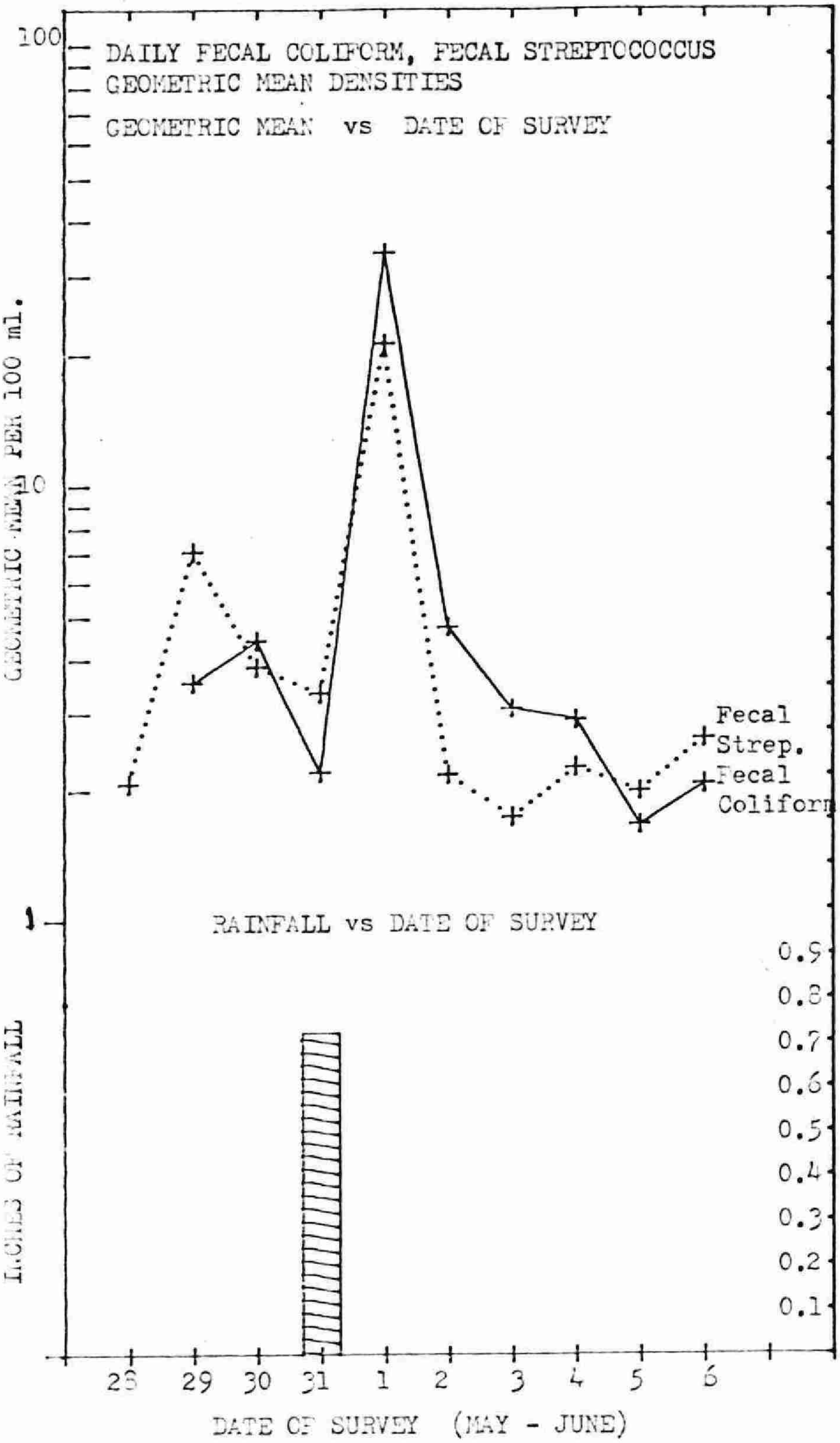
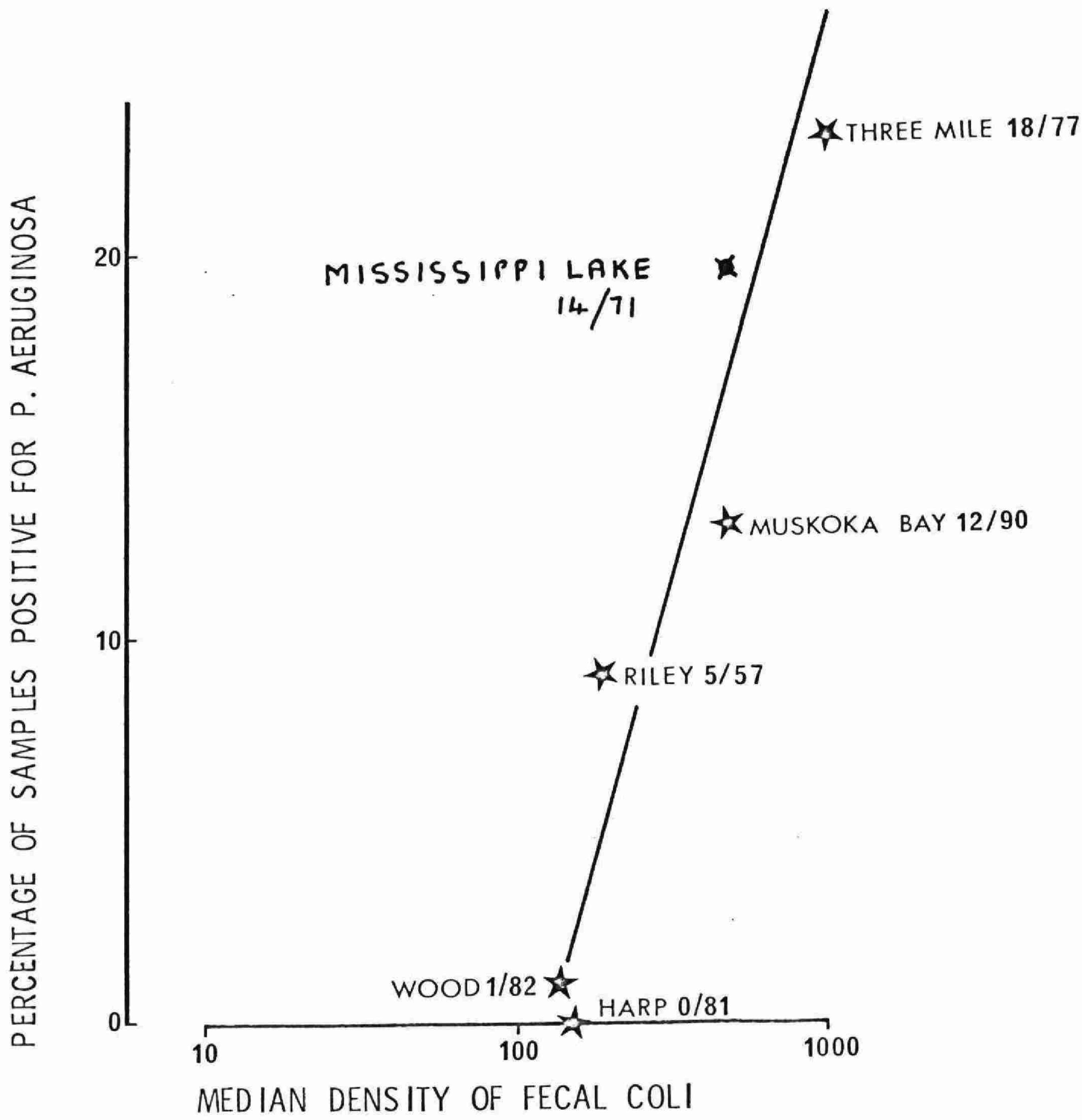

DAILY FECAL COLIFORM, FECAL STREPTOCOCCUS
GEOMETRIC MEAN DENSITIES
GEOMETRIC MEAN vs DATE OF SURVEY
GEOMETRIC MEAN PER 100 ml.
100
10
1
Fecal
Strep.
Fecal
Coliform
RAINFALL vs DATE OF SURVEY
INCHES OF RAINFALL
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
28
29
30
31
1
2
3
4
5
6
DATE OF SURVEY (MAY - JUNE)

FIGURE 8. BETWEEN LAKES COMPARISON P. AERUGINOSA IN SEDIMENT



DATE DUE
